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# Effects of Amendments in Nitrogen, Phosphorus, Potassium, Zinc and Gypsum on the Quality of the Rice Grain, in Salinity Conditions

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**Abstract :** This study is to investigate the effects of the amendments in macronutrients nitrogen-phosphate-potassium (NPK) and microelements zinc and gypsum on physicochemical qualities of rice grain. The design is a split plot with two factors: fertility with 12 levels of fertilizers and variety with 6 rice varieties, repeated in 3 blocks, in two different media, including a salty medium (MS) and a unsalted medium (MNS). Six (6) rice varieties were used, of which four (4) tolerant varieties, and two (2) controls varieties that are moderately sensitive and very sensitive respectively. Results show a total yield milled grain of tolerant varieties, highest in saltwater environments as in unsalted middle, while the opposite effect is observed with susceptible varieties. The highest yields milled total grains were observed in a saltwater medium, with the formula 120-26-50 with or without zinc or Gypsum. In unsalted medium, it is the formula 0-26-50 with or without zinc or gypsum, which gives the best yields total milled grains. Broken grains have best performance in a saltwater environment, whatever variety or combination of fertilizer used. Weight of 100 grains is more efficient in unsalted environment, whatever variety or combination of fertilizer used. Depending on the alkaline spreading value (ASV), varieties can be divided into two groups. Varieties of the first group with low AVS (3 to 4) have a gelatinization temperature (GT) intermediate. Those in the second group, with a middle and higher AVS (5.4 to 6), have low gelatinization temperature. The varieties of this last group with low GT, are more interesting for the market and consumers because they require only a low cooking time.

**Keywords**: irrigated rice, grain yield, quality, Salinity, fertilization, alkaline spread value (ASV), gelatinization temperature (GT).

## Introduction

Rice is one of the major cereal that is the staple food of nearly a third of the world population (Zhao et al., 2011). It is produced in about 110 countries, including most countries in West Africa. Most of the rice consumed in Senegal is imported from Asian countries with a consumption of 90 kg per capita (FAO, 2012). Low rice production at the national level, significantly lower than the demand and marketing difficulties related to product quality have long limited the competitiveness of locally produced rice. After the yield, grain quality is the most important factor considered by breeders and consummers to achieve self sufficiency in rice (Juliano and Duff, 1991). One of the current challenges for a country that wants to emerge is to use precision agriculture to reduce the problems related to food insecurity and meet the future needs of the population, while preserving a healthy environment. However, abiotic stresses such as soil salinity is a major constraint for the environment but above all for the sustainable improvement of the quality of the rice grain, and yields in whole grains. Many authors of which Alam et al. (2009) have shown that a judicious and appropriate use of fertilizers can increase yields and improve the quality of rice. In fact, fertilizers are factors of intensification of production systems, whose profitability depends largely on the quality of fertilizers used (Tabar 2012). To overcome this constraint, which impacts negatively on the development of rice farming, various research has been initiated to create rice varieties tolerant to salinity (Bimpong et al, 2016) as well as many combinations of fertilizers to optimize


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production in both normal and saline conditions. However, grain yield generally being the final objective, it is also important to study if fertilizer inputs has an impact or not on the quality of the rice grain. It is in this perspective that this study was initiated. The main objective is to analyze the influence of various chemical fertilizers on the quality of the rice grain. More specifically, this study aims to (i) compare the effects of NPK, alone or combined with zinc or gypsum, the physicochemical characteristics of the rice grain, and (ii) to identify the best fertilizer formula under conditions of salinity.

**Material and methods**

*Area description*

This study was conducted at the experimental station of the Africa Rice Center (AfricaRice), based in Ndiaye, 35 km from Saint-Louis, in the Delta of the Senegal River Valley. The study was conducted during the hot dry season in two different media, including a unsalted medium (MNS), containing freshwater, and saltwater medium (MS).

*Evolution of the Electrical Conductivity (EC)*

The first measurement was made at transplanting seedlings whose seeds were sown three weeks previously in nurseries. During the experiment, the electrical conductivity remained high in salt medium between 4 dS / m and 8.5 dS / m. In unsalted medium by against, it remained low with values less than 1 dS / m (Figure 1). We note that over time, the EC decreases when rice is grown in a saltwater environment.

*Plant Material*

The plant material is composed of six rice varieties including 2 controls as Sahel 108 and IR 31785, which are respectively medium and high salt-sensitive and four tolerant varieties like IR 4630-22-2-5-1-3, IR 59418- 7B-21-3, IR-76346 BB-10-1-1-1, IR-72 593 B-3-2-3-8 (Table 1). Sahel 108 was the local variety released in Senegal and well appreciated by farmers. Other varieties are introduced and are in the testing phase.

*fertilizers*

Twelve (12) Mineral fertilizer levels combining elements N-P-K and optional zinc or gypsum were applied at different doses (Table 2). For fertilization, nitrogen inputs with 60 kg / ha, 120 kg / ha and 150 kg / ha as urea have been divided in 3 successive applications made to early tillering stage, the stage of panicle initiation and 10 days before flowering. The others fertilizers were introduced in one portion as basal dressing with 26 kg / ha of P as triple super phosphate (TSP), 50 kg / ha of K as KCl, 10 kg / ha of Zn under form of zinc sulfate and 100 kg / ha of gypsum

*Experimental design*

The experimental design is a two-factor split plot with 3 repetitions and 2 environments. The main factor is composed of 12 levels of fertilizer and the secondary factor is represented by 6 rice varieties. The study was conducted in two different media with a salt medium (MS) with a salinity level ≥ 3 dS / m, and a unsalted medium (MNS) using freshwater.

The trial was set up in large plots or sub-blocks of 50.1 m2 and small plots or sub plots of 8 m2. The main plots were separated by wide bunds to minimize lateral percolation of water between two plots. The layout of the unit plot is illustrated in Figure 2.

*Parameters studied*

*Humidity*

A small amount of each sample of 125 g of clean paddy will be used to measure the moisture content that will enable calculating the paddy weight adjusted to 14% which is the weight of paddy used brought to a moisture content of 14 % according to the following relationship:

$$\text{Weight adjusted to 14\%} = \frac{(100 - Moisture\ read\ rate)}{(100-14)} \times Sample\ weight$$

*Grain size (paddy and brown rice)*

This is the length and the width of the grain. They are measured on 10 grains of paddy and brown rice. The length to width ratio gives the shape of the grain. A scale of rice grains classification according to their form is given by the Standard Evaluation System (IRRI, 1980) (Table 3).

*Yield after processing*

It is obtained by the following report:

$$\text{\% Yield after processing} = \left(\frac{\text{Total weight milled rice}}{\text{Weight adjusted to 14\%}}\right) \times 100$$

*Percentage of whole grains*

It is determined by the ratio:

$$Whole\ grins\% = \left(\frac{Weight\ of\ whole\ grains}{Weight\ adjusted\ to\ 14\%}\right) \times 100$$

*Percentage of broken grains*
It is obtained by the difference between the yield after processing and the percentage of whole grains:

$$\% \, Borken \, grains = \% Yield \, after \, processing - \% Whole \, grains$$

*Weight of 100 grains of paddy*
It is obtained by simple weighing. But these 100 grains must be properly chosen to be representative for each variety.

*Gelatinization temperature (GT)*
Gelatinization temperature of the starch is a parameter assessed using a test called alkaline test or test ASV "Alkali Spreading Value". The alkali test determines the energy needed for cooking and water absorption during cooking. More the alkali spread value is, the more the GT is high.

Whitened rice grains are steeped for 13 hours minimum in the alkaline solution, because of 6 good grains (whole grain not moldy and not chalky) per petri dish containing 10 ml of alkaline solution; the grains are arranged such that they do not touch (IRRI, 1996). The alkali spread value is a simple indicator. Note 2 is given to intact grains; 3 for whole grains with mild to moderate dispersion; 4 for the grains with collar surrounding the grain; 5 for severely scattered grains; 6 for the grains with the cotton-shaped center and 7 for completely dissolved grains (Figure 9). The notation is visual and is based on the method of Jennings et al. (1979).
*Statistical Analyses*

Statistical analysis of the data was performed with the software "Statistical Analysis System" version 9 (SAS Institute, 2002). Furthermore, comparison of averages was carried through the Duncan test at the 1% and 5%.

**Results**
*Statistical analysis of data on physical and chemical characteristics of the rice grain*
The results of the analysis of variance are given in Table 4.

It appears from the analysis of variance that there has a variety x fertilizer interaction only with the ASV parameter. For other parameters, there's no interaction and therefore the varieties and fertilizers can be analyzed separately. The variety does not affect fertilizer and vice versa. By against, with the alkali test (ASV), both treatments (fertilizers and varieties) are linked and any interpretation of one must take into account the other.

*Whitened total grain yield (%)*
The results obtained with the fertilizer formulas are applicable for all varieties because there is no interaction variety x fertilizer.
For the characters studied in both salty medium (MS) and unsalted (MNS), the results show that there's a significant difference (P <5%) to highly significant between combinations of fertilizer. A highly significant difference (P <1%) also exists among varieties for all the variables studied (Table 4). In MS medium, the highest yield grain milled total (65.94%) is obtained with the formula 120-26-50 fertilizer with or without zinc or gypsum while in MNS medium the best performance was obtained with the formula 0-25-50 with or without zinc or gypsum (Figure 3).

*Whole grain yield (%)*
Analysis of variance showed a highly significant difference (P <1%) between varieties in both media. In MS, it is the IR 4630-22-2-5-1-3 tolerant variety that has the best performance in whole grains with an average of 50.38%, while in MNS is the tolerant variety IR 76346-BB -10-1-1-1 which presents the best performance with 59.69% (Figure 4c). The lower yields of whole grain on both media were obtained with the highly susceptible variety IR 31785-58-1-2-3-3 with 33.99% and 43.48% respectively in MS and MNS (Figure 4c).

*Broken grain yield (%)*
There is a highly significant difference (P <1%) between varieties for both environments. Between the fertilizer formulas, there is a significant difference (P <5%), in unsalted environments and a non-significant difference in salty environments (Table 4). Of all the varieties (Figure 4c and 4d1), and combinations of fertilizers (Figure 4d2), the rate of broken grains is higher in salinity conditions than in freshwater conditions. Thus, salinity seems to favor yields broken grains.

*Weight of 100 grains of paddy rice (g)*
Between combinations of fertilizer, the weight of 100 grains is significant (P <5%) in MNS medium, and is highly significant (P <1%) in MS medium. Between varieties, this characteristic is highly significant (P <1%) in both media (Table 5). Of all the varieties and combinations of fertilizers, weight of 100 grains is higher in non-saline environment, as in a saltwater environment (5e and 5f). The best rates were obtained with the formula 60-26-50, in a saltwater environment, and the formula 150-26-50 + gypsum in non-salty environment (Figure 5e).

*Grain shape*
In saltwater, the grain length was highly significant (P <1%) between varieties and between fertilizer formulas. In unsalted medium, this variable is also highly significant among varieties (Table 4). The length / width ratio (L / W) of the rice grains shows a highly significant difference (P <1%) between varieties on all media.

*Alkali spreading value (ASV)*
The interaction variety and fertilizer formula (G * N) for ASV variable present a significant difference in a saltwater environment. The average value of ASV for each variety was declined in Table 5. It is observed that varieties like Sahel 108, IR 31785-58-1-2-3-3, IR 4630-22-2-5-1-3, IR-59418-7B 21-3, and IR 72593-B-3-2-3-8 show low ASV which varies very little according to the different combinations with values between 3 to 3.6, except for variety IR 72593-B-3-2-3-8 whose AVS value highly varies according to the fertilizer formulas, with value betweed 3 and 5.4. The gelatinization temperature (GT) of these varieties will be intermediate. In contrast, variety IR-B-76346 B-10-1-1-1 has a high ASV which varies slightly according to different formulas with values between 5.5 and 6. This means that this variety has a low gelatinization temperature. The highest ASV value was obtained with the formula 150-26-50 + Zn, while the lowest values of ASV were observed with non-fortified fertilizer formulas with zinc or gypsum. Depending on the value of the ASV, the varieties were classified into two groups with one group composed of low ASV varieties, which have a gelatinization temperature (GT) intermediate, and a second group, represented by one variety, with high ASV, which present a low gelatinization temperature (Figure 6).

**Discussions**
The objective of this study was to characterize the effect of mineral fertilizers reinforced with zinc or gypsum on the physicochemical characteristics of the grain of 6 varieties of rice in irrigated condition through two different media including a salt medium and not salted. The results showed better yields whitened grains in salted environment than unsalted environment. The 120-26-50 fertilizer formula is the combination of NPK recommended and vulgarised in the Senegal River valley. It gives the best performance in seeds, in unsalted environment. In saltwater environments complement gypsum improves grain yields. By cons, this additional contribution gypsum causes a drop in yield from 1.43% in environment unsalted. These results confirm those of Muhammed et al. (1986), and Xiong et al. (2008), which showed that gypsum intake promotes better tolerance of the plant to salt and that the nitrogen intake may increase the rate of milled rice. The results show better performance tolerant varieties in whole grains, both in salty environment than unsalted environment compared to susceptible varieties. These sensitive varieties develop rather more broken grains in both media, unlike the tolerant varieties, which show a lower breakage rate (<25%). These results could be explained by the effect of the formula 150-26-50 + zinc on tolerant varieties, which have less broken rice which greatly increases the efficiency of the machining. These results corroborate those of Sartaj et al. (2001) and Dilday (1987), which show a negative correlation between rate and broken rice rate of whole grain in nitrogen deficiency condition. The best performance on the weight of 100 paddy rice grains were obtained from varieties 4630-22-2-5-1-3 IR and IR 72593-B-3-2-3-8 in a saltwater environment. The best weight 100 grain were obtained with the formula 60-26-50, in a saltwater environment and the formula 150-26-50 + gypsum in unsalted environment. This suggests a significant influence of the nitrogen factor on grain weight, particularly salinity conditions with gypsum addition. These results are similar with those Sartaj et al. (2001), which showed positive correlations between the thousand grain weight and the nitrogen supply, and those Rasouli et al. (2013), who showed an improvement of the weight of 100 grains of wheat with an addition of gypsum. In both environments, the ASV different varieties varies little from one medium to another. This is explained by the fact that the ASV is not affected by salt stress. The alkalinity distribution value and consistency of the gel are not affected by growing rice in saline soil (Siscar-Lee et al., 1990). Compared to the interaction varieties x fertilizers, varieties Sahel 108 IR31785-58-1-2-3-3, IR4630-22-2-5-1-3, IR59418-7B-21-3, and IR72593-B-3-2-3-8, have an average ASV with all combinations of fertilizer therefore their gelatinization temperature will be between 70 and 74 ° C. Tolerant variety IR76346-BB-10-1-1-1 shows high ASV (between 5.5 and 6) with all combinations except for the formula 120-26-50 + gypsum, where there is an average ASV (3.72) . The gelatinization temperature will be low and less than 70 °C for all combinations of fertilizer except for the formula 120-26-50 + gypsum where the GT will be between 70 and 74 °C.

**Conclusion**
This study allowed to characterize the effect of mineral amendments on the quality of the rice grain. The various formulas tested showed effects on the physicochemical characteristics of the grain, as in MS MNS. The formula 120-26-50 with gypsum addition promotes an increase in total grain yield whitened in MS. This is an interesting result that helps mitigate the low yields of grain whitened in salinity condition. In environment unsalted, the formula 150-26-50 + Zinc promotes a reduction in the rate of broken grains of up to 10.94% compared to the results obtained in a saltwater environment. Variety IR76346-BB-10-1-1-1 with low gelatinization temperature is very promizing for consumer in the région according to deficit of energy in the région.

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**Table 1 :** list of varieties

| N° | Names of varieties | Level of Salinity tolérance |
|---|---|---|
| V1 | Sahel 108 | Control sensitive |
| V2 | IR 31785-58-1-2-3-3 | Control sensitive |
| V3 | IR 4630-22-2-5-1-3 | Tolerant |
| V4 | IR 59418-7B-21-3 | Tolerant |
| V5 | IR 76346-B-B-10-1-1-1 | Tolerant |
| V6 | IR 72593-B-3-2-3-8 | Tolerant |

**Table 2:** list of fertilizers

| N° | Levels of fertilizers |
|---|---|
| T1 | 0-26-50 |
| T2 | 60-26-50 |
| T3 | 120-26-50 |
| T4 | 150-26-50 |
| T5 | 0-26-50 + Zn (10 $kg.ha^{-1}$) |
| T6 | 60-26-50 + Zn (10 $kg.ha^{-1}$) |
| T7 | 120-26-50 + Zn (10 $kg.ha^{-1}$) |
| T8 | 150-26-50 + Zn (10 $kg.ha^{-1}$) |
| T9 | 0-26-50 + gypse (100 $kg.ha^{-1}$) |
| T10 | 60-26-50 + gypse (100 $kg.ha^{-1}$) |
| T11 | 120-26-50 + gypse (100 kg.ha-1) |
| T12 | 150-26-50 + gypse (100 $kg.ha^{-1}$) |

T=Treatment

**Table 3 :** Scales of the Standard Evaluation System (IRRI, 1996)

| Scale | Length | Sharpe | Ratio L/l |
|---|---|---|---|
| 1 Extra long | > 7.5 mm | 1 Slim | > 3.0 mm |
| 3 Long | entre 6.6 et 7.5 mm | 3 Average | Between 2.1 and 3.0 mm |
| 5 Medium | entre 5.5 et 6.6 mm | 5 Oval | Beteen 1.1 and 2.0 mm |
| 7 Short | < 5.5 mm | 9 Round | < 1.1 mm |

**Tableau 4 :** Average squares of physico-chemical characteristics of grain of rice varieties in salted and unsalted medium

| | | Average square in salted medium | | | | | | | Average square in unsalted medium | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source of variation** | ddl. | G T. | G. E. | Brisures | P. 100 grains | Longueur (L) | Rapport (L/l) | ASV | G.T. | G.E. | Brisures | P. 100 grains | Longueur (L) | Rapport (L/l) | ASV |
| **Repetition** | 2 | 14.23 | 469.43** | 346.57** | 0.30** | 0.82** | 0.06 | 0.42* | 3.38 | 5.98 | 4.57 | 0.01 | 0.32 | 0.25** | 4.63** |
| **Fertilizer** | 11 | 16.15* | 59.13 | 28.31 | 0.07** | 0.18** | 0.02 | 0.48** | 7.20* | 38.22 | 36.56* | 0.03* | 0.1 | 0.04 | 0.22 |
| **Repetition*Fertilizer** | 22 | 11.19 | 141.74** | 109.07** | 0.17** | 0.15** | 0.03 | 0.17 | 4.24 | 26.05 | 22.2 | 0.02* | 0.09 | 0.03 | 0.19 |
| **Varieties** | 5 | 64.98** | 1164.8** | 1007.92** | 2.31** | 5.27** | 3.74** | 42.18** | 73.65** | 1186.21** | 951.73** | 2.09** | 3.14** | 3.57** | 40.57** |
| **Fertilizer*varieties** | 55 | 6.88 | 30.96 | 23.64 | 0.02 | 0.06 | 0.04 | 0.33** | 3.66 | 28.05 | 25.5 | 0.01 | 0.07 | 0.03 | 0.17 |
| **C.V. (%)** | - | 4.47 | 17.03 | 28.23 | 6.93 | 4.36 | 6.45 | 9.86 | 2.93 | 9.36 | 32.09 | 4.81 | 5.26 | 6.57 | 13.49 |

ddl. = degree of freedom ; G.T.= total grain ; G.E.= whole grain ; P.100 grains = weight of 100 grains of paddy ; ASV = alkaline spread value

* = 0.01< P < 0.05 = significant difference ; **= < 0.01 = highly significant difference ; C.V.=coefficient of variation ; L/l = Length over width

**Table 5 : Mean value of the ASV of varieties studied**

| Varieties | Mean value of ASV | GT |
|---|---|---|
| S108 | 3.1 | Intermediate |
| IR31785-58-1-2-3-3 | 3.25 | Intermediate |
| IR4630-22-2-5-1-3 | 3.3 | Intermediate |
| IR59418-7B-21-3 | 3.5 | Intermediate |
| IR72593-B-3-2-3-8 | 4.5 | Intermédiate |
| IR76346-B-B-10-1-1-1 | 5.75 | Low |

ASV : Alkali Spreading Value
GT : Gelatinization temperature

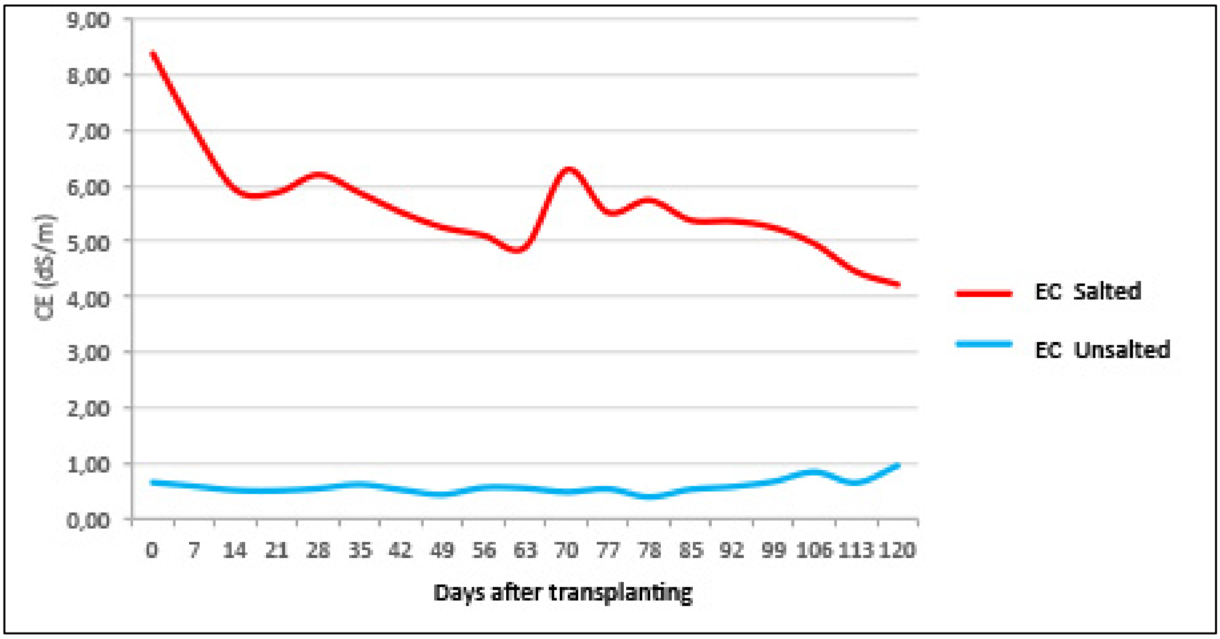


**Figure 1 :** Evolution of the electrical conductivity in a saltwater environment and unsalted

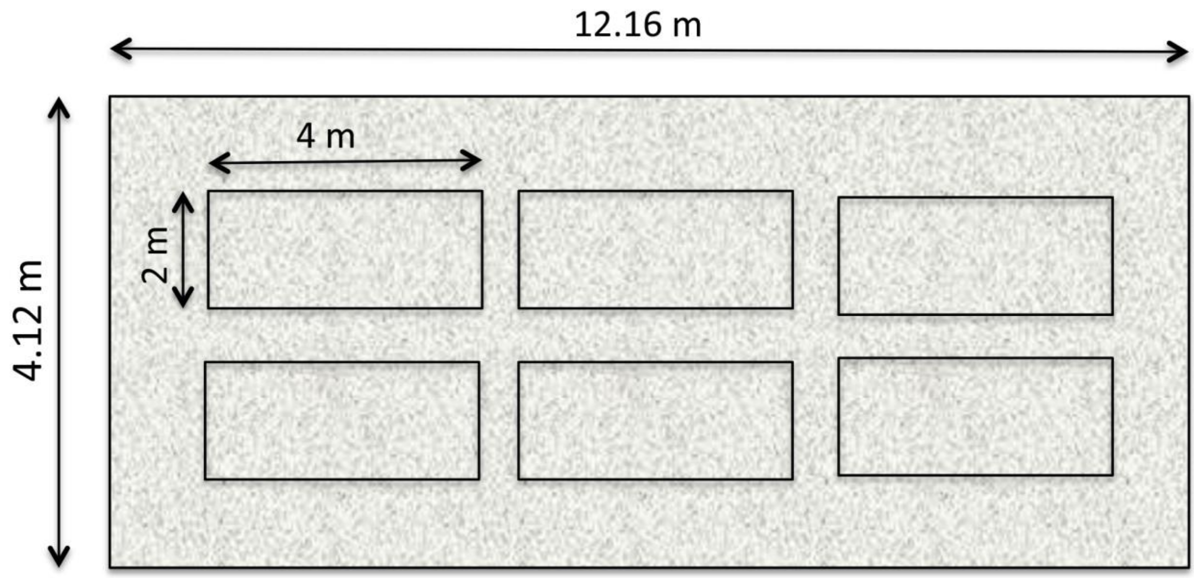


**Figure 2 :** Single plot

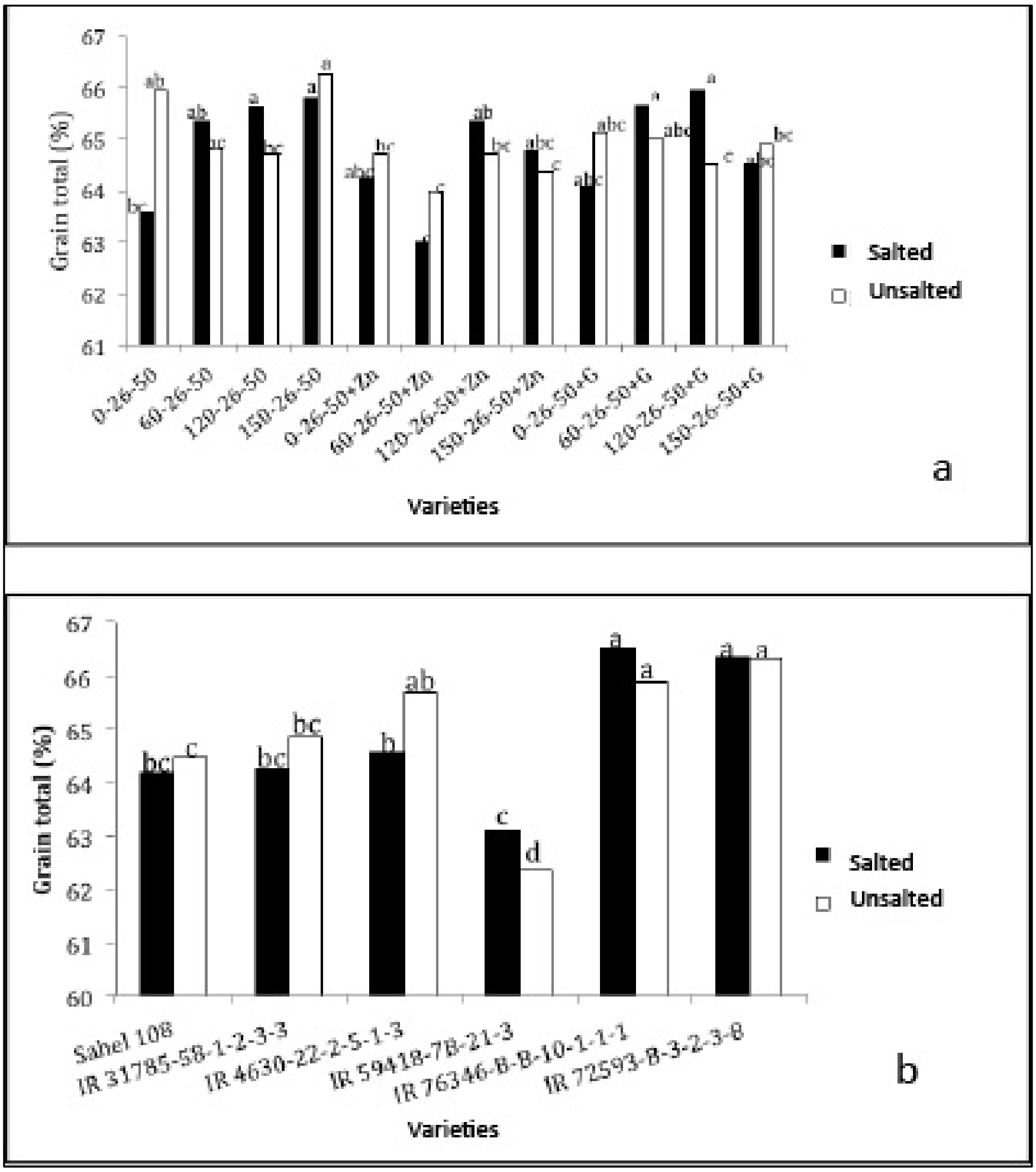


**Figure 3 :** Comparison of total grain average yield bleached in a saltwater environment and unsalted between combinations of fertilizer (a) and between varieties (b)

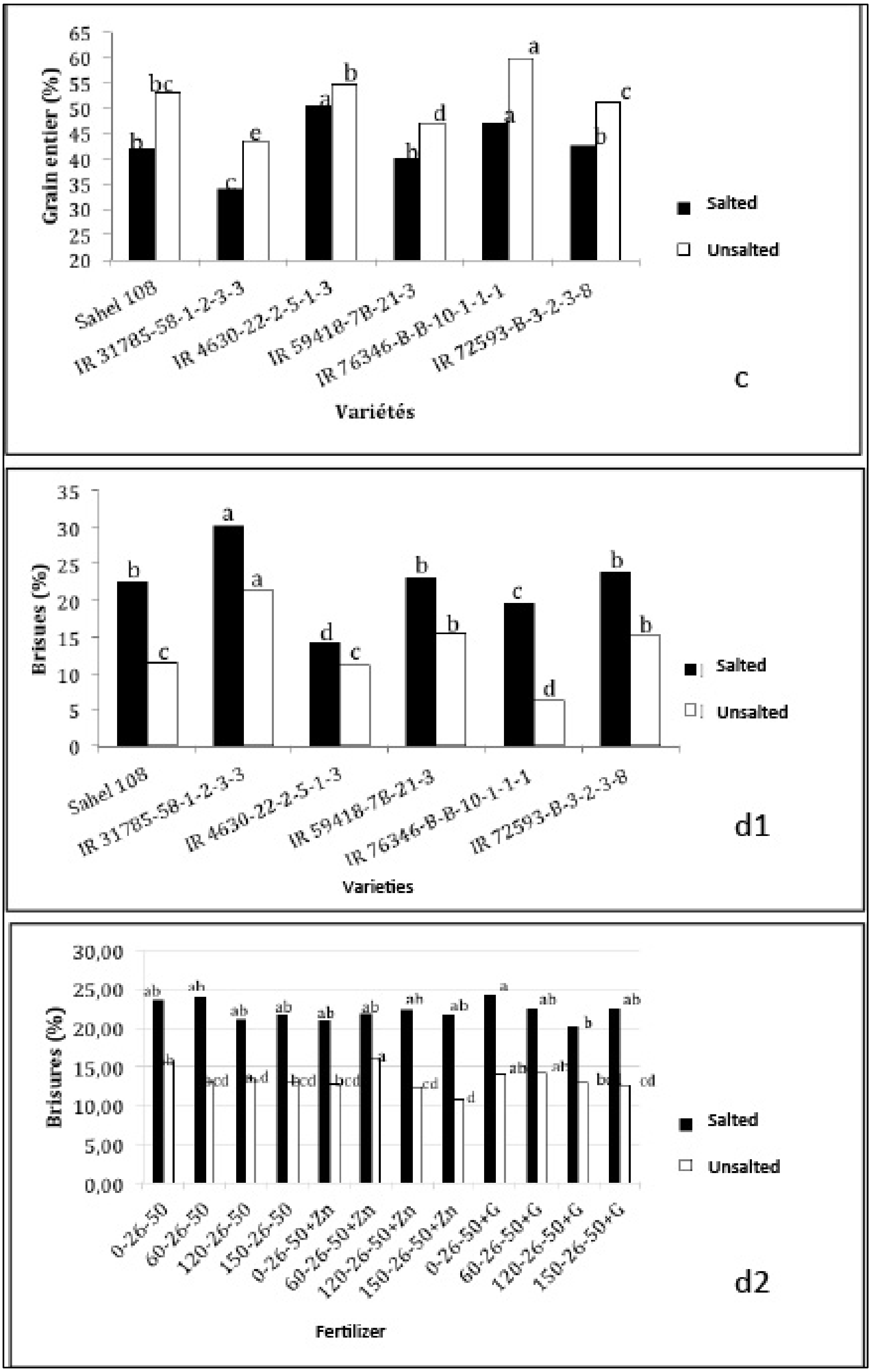


**Figure 4:** Comparison of average yields in whole grains (c) and broken grains (d1 and d2) in a saltwater environment (MS) and unsalted environment (MNS) between varieties (c and d1), and between combinations of fertilizers (d2 )

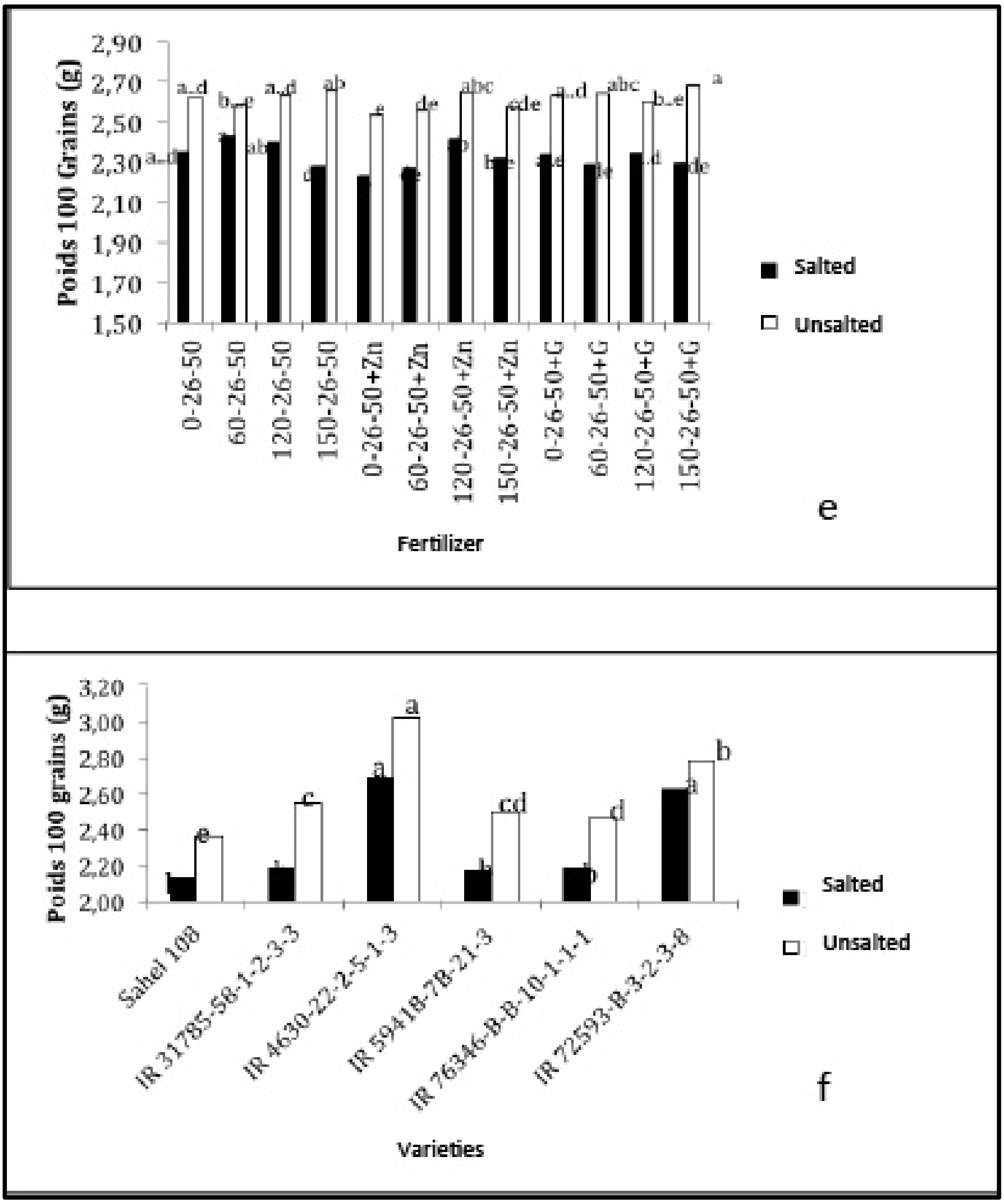


**Figure 5 :** Comparison of average weight of 100 grains in a saltwater environment (MS) and unsalted environment (MNS) among the combinations of fertilizer (e) and between varieties (f)

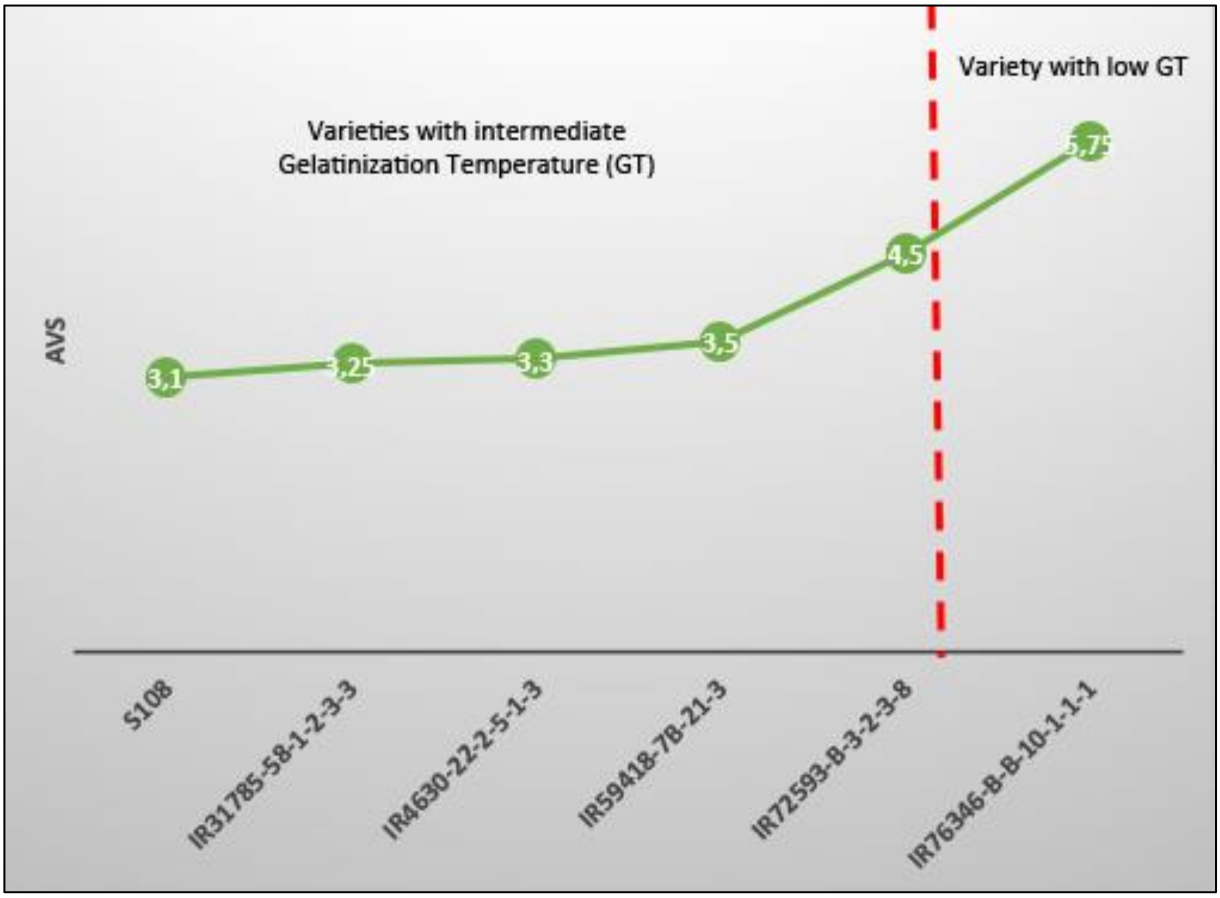


**Figure 6** Classification of varieties according to the value of the ASV (Alkaline Spreading Value)